WHAT IS CLAIMED IS:

1. A method of magnetic gradient waveform design for rapid magnetic resonance imaging using constrained optimization comprising the steps of:

a) selecting a number N of discrete-time waveforms with a sampling period , τ, and time $T=N\tau$,

b) expressing constraints as equations,

c) identifying if a solution exists for T, and if not, increasing T until a solution exists,

d) decreasing T to find a shortest solution, and

e) solving the equations to identify the solution.

2. The method as defined by claim 1 wherein step e) utilizes linear programming to identify the solution.

3. The method as defined by claim 2 wherein the linear programming finds the vector x that minimizes a cost function $f^T x$ subject to the constraint $Ax =< b$, where matrix A and vector b are formed by combining all of the linear constraint equations for the amplifier and pulse sequence constraints.

4. The method as defined by claim 1 wherein steps c), d), and e) utilize L1-norm formulation.

5. The method as defined by claim 4 wherein the gradient is one dimensional.

6. The method as defined by claim 4 wherein the gradient is two dimensional.

7. The method as defined by claim 4 wherein the gradient is three dimensional.

8. The method as defined by claim 4 wherein in step a) the gradient amplifier has current and voltage limits (I_{max} and V_{max}) that result in the following limits on G(p):

$|G(t)| \leq \eta I_{max}$

and

$$\left| L\frac{d}{dt}G(t) + RG(t) \right| \leq \eta V_{\max}$$

where L, R, and η are the gradient coil inductance, resistance, and efficiency.

9. The method as defined by claim 1 wherein steps c), d), and e) include adding slack variables to the optimization.

10. The method as defined by claim 9 wherein step e) solves for gradient Gx(n) and a set of variables H_x(n) that converge to |Gx(n)| and a set of variables S_x(n) that converge to |αGx(n) + βGx(n+1)|.

11. The method as defined by claim 10 wherein the slack variables are forced to converge by adding linear gradient constraints:

$$-H_x[n] + G_x[n] \leq 0$$
$$-H_x[n] - G_x[n] \leq 0$$

and slew-rates constraints:

$$-S_x[n] + \alpha G_x[n] + \beta G_x[n+1] \leq 0$$
$$-S_x[n] - \alpha G_x[n] - \beta G_x[n+1] \leq 0$$

whereby the constraints force the Hx(n) and Sx(n) variables to approach an appropriate absolute value when combined with minimization of the following pulse function:

$$J(S_x[n], H_x[n]) = \sum_{n=1}^{N} (H_x[n] + S_x[n]).$$

12. The method as defined by claim 1 wherein step e) utilizes second-order cone programming (SOCP) to find a solution x that minimizes a linear pulse function $f^T x$ subject to a second order cone constraint

$$\|Ax + b\|_2 \leq Cx + d$$

which is a superset of the linear constraints in linear programming where matrix A and vector b are formed by combining all linear constraint equations for amplifier and pulse sequence constraints.

13. The method as defined by claim 1 wherein steps c), d) and e) use a binary-search to minimize time in identifying the minimum value of n which provides a solution.

14. The method as defined by claim 13 wherein the gradient is one dimensional.

15. The method as defined by claim 13 wherein the gradient is two dimensional.

16. The method as defined by claim 13 wherein the gradient is three dimensional.

17. The method as defined by claim 13 wherein in step a) the gradient amplifier has current and voltage limits (I_{max} and V_{max}) that result in the following limits on G(p):

$$|G(t)| \leq \eta I_{max}$$

and

$$\left| L\frac{d}{dt}G(t) + RG(t) \right| \leq \eta V_{\max}$$

where L, R, and η are the gradient coil inductance, resistance, and efficiency.

18. The method as defined by claim 1 wherein the gradient is one dimensional.

19. The method as defined by claim 1 wherein the gradient is two dimensional.

20. The method as defined by claim 1 wherein the gradient is three dimensional.

21. The method as defined by claim 1 wherein in step a) the gradient amplifier has current and voltage limits (I_{max} and V_{max}) that result in the following limits on G(p):

$$|G(t)| \leq \eta I_{max}$$

and

$$\left| L\frac{d}{dt}G(t) + RG(t) \right| \leq \eta V_{\max}$$

where L, R, and η are the gradient coil inductance, resistance, and efficiency.

22. The method as defined by claim 1 and further including:

f) establishing physical constraints of a gradient amplifier and a gradient coil.

23. The method as defined by claim 22 and further including:

g) establishing beginning and end gradient boundary constraints and fixed area for one or more gradient moments.

24. The method as defined by claim 1 and further including:

f) establishing beginning and end gradient boundary constraints and fixed area for one or more gradient moments.

25. The method as defined by claim 1 wherein step b) includes gradient heating constraints.

26. The method as defined by claim 25 wherein step b) includes gradient magnetostimulation constraints.

27. The method as defined by claim 1 wherein step b) includes gradient magnetostimulation constraints.